——————————— (1982): Desmids of Karnataka State and Goa Part I. *Phykos, 21*: 143-149.

Bongale, U. D. & Bharati, S. G. (1980): Freshwater algae of Davanagere and Raichur of Karnataka State, India. *J. Bombay nat. Hist. Soc., 77*: 6-11.

Gonzalves, E. A. (1981): Oedogoniales. ICAR, New Delhi, pp. 757.

Grönblad, R. & Croasdale, H. (1971): Desmids from Namibia (S. W. Africa). *Acta Botanica Fennica, 93*: 1-40.

Gurudeva, M. R., Govindappa, A. & Somashekar, R. K. (1983): Desmid flora of Savanadurga, Karnataka. *Phykos, 22*: 48-56.

Hegde, G. R. & Bharati, S. G. (1983): Freshwater algae of Bijapur District, Karnataka State, India. *Phykos, 22*: 167-170.

Hirano, M. (1967): Freshwater algae collected by the joint Thai-Japanese Biological Expedition to South East Asia. 1961-62. *Nature and Life in South East Asia, 5*: 1-71.

——————— (1969): Freshwater algae from Rangtang Himal, Nepal Himalaya. *Contr. biol. Lab. Kyoto Univ. 22*: 1-42.

Hosmani, S. P. & Bharati, S. G. (1983): Euglenineae of polluted and unpolluted waters. *Phykos, 22*: 130-135.

Philipose, M. T. (1967): Chlorococcales. ICAR, New Delhi, pp. 365.

——————— (1982): Contributions to our knowledge of Indian algae-III. Euglenineae Part I. The genus Euglena Ehr. *Proc. Indian Acad. Sci., 91*: 551-599.

Prescott, G. W. (1951): Algae of the Western Great Lakes Area (Exclusive of Desmids and Diatoms). Cranbrook Inst. Sci. Publ. pp. 946.

Sarma, Y. S. R. K. & Khan, M. (1980): Algal Taxonomy in India. Botanical Records and Monographs-2. pp. 153.

Scott, A. M. & Prescott, G. W. (1961): Indonesian Desmids. *Hydrobiologia, 17*: 1-132.

Therezien, Y. & Coute, A. (1977): Algues D'ean Douce des Iles Kerguelen *et* Crozet (a 'l' exclusion des Diatom'ees). *CNFRA, 43*: 1-91.

42. LIMNOLOGY OF THE THERMAL SPRINGS OF ORISSA

(*With two text-figures*)

The physico-chemical characteristics and floristic life of the two thermal springs of Orissa state — Taptapani in Ganjam dist. and Autri in Puri dist. had been investigated for one year. The temperature of the thermal springs remained almost constant during the period of investigation. The water of both the springs were alkaline with a pH between 9.2 to 9.6. No carbon dioxide and only traces of nitrate, nitrite and phosphate was detected. A number of blue-green algae and diatoms and few zooplanktons were recorded in these hot water springs. The quantity of plankton was maximal in the main tank of Taptapani and only in the overflows of Autri. None of the organisms except the blue-green algae *Mastigocladus laminosus* (Cohn) and *Oscillatoria teribriformis* (Ag.) and the diatoms: *Navicula* sp. and *Cyclotella* sp. were found in the main tank of Autri at 55°C.

Introduction

Extensive reports are available on the limnology of several thermal springs of U.S.A., Europe, Japan, Israel and New Zealand (Castenholz 1967, 1968, 1969, 1970; Brock & Brock 1966, 1967, 1968, 1969; Peary 1964, Stockner 1967, 1968; Emoto 1967, Kahan 1969). Most of the investigations aimed at elucidating the upper temperature limit of life and to report on the organisms that occur in the hot springs. Though India has over three hundred hot water springs (Oldham & Oldham 1882), our knowledge on the organisms inhabiting high temperature habitats is very meagre. Kirtikar (1886) was the first to record a thermal alga from India.

Drouet (1938) described a few thermal alga during the Yale North Indian Expedition. Prasad & Srivastava (1965) and Thomas & Gonzalves (1965) have given an account of blue-green algae vegetation on the thermal springs of Himachal Pradesh, Gujarat and Maharashtra. Vasistha (1968) studied extensively the algal flora and the chemical constituents of about a hundred thermal stations distributed all over India. But the psysico-chemical nature of the thermal water and the organisms inhabiting the two thermal springs of Orissa have not been investigatso far. The present investigation was aimed at determining the physico-chemical characteristics of the thermal water and the flora and fauna of the hot water springs of Taptapani (in Ganjam dist.) and Autri (in Puri dist.) of Orissa state, India.

Location and Description of the study sites

1. *Taptapani*:

This hot spring is situated at a distance of 56 kilometres (south wards) from Berhampur (19° 16′ N, 84° 53′ E) near a small village called Taptapani. It has a main tank, octangular in shape (constructed with bricks and cement by the local people) from where the mineral water and gases in the form of bubbles continuously escape (Fig. 1). Each arm of the tank is 104″ in length and are 120″ apart from one another. It has a outlet through which the water over flows. In the main tank the water level varies at different spots and its sandy bottom is full of rocks. The overflows are cemented at the bottom and are used for bathing purpose. The length, breadth and water height of 1st and 2nd over flows are 232″ × 104″ × 26″ and 105″ × 104″ × 23″ respectively. From the 2nd over flow water flows to the out side. It is believed that the water has therapeutic properties.

2. *Autri*:

This thermal spring is situated at a distance of 43 kilometres (west wards) from Bhubaneswar (20° 12′ N, 85° 22′ E) near a small village called Baghamari. It has a circular main tank of 161″ diameter and 168″ depth (artificially constructed) from where water and gases escape from the bottom in the form of bubbles (Fig. 2). Similar to Taptapani it has a rocky bottom but the water depth is very deep (139″). Just above the water level there are two separate outlets through which water flows to the two separate cemented bathing tanks (overflows). The 1st and 2nd overflows are placed at 77″ and 334″ distance from the main tank with an area of 135″ × 135″ and 120″ × 120″ respectively. Both the overflow tanks have around 40″ of water height throughout the year and from these tanks water flows to the surrounding rice-fields.

Methods

Water samples with different algal mats were collected from the main tank and the overflows of Taptapani and Autri between July 1981 and May 1982 at regular intervals. Temperature was recorded on the spot with a mercury thermometer graduated upto 100°C. The hydrogen-ion-concentrations of the thermal water was determined by using a digital pH meter. Water samples collected during February 1982 from both the thermal springs were analysed for the presence of various chemicals according to the standard methods for the examination of water and waste water (1965) and were indicated in parts per million. Plankton samples were collected by filtering known quantity of the water taken from different spots of the main tank and the

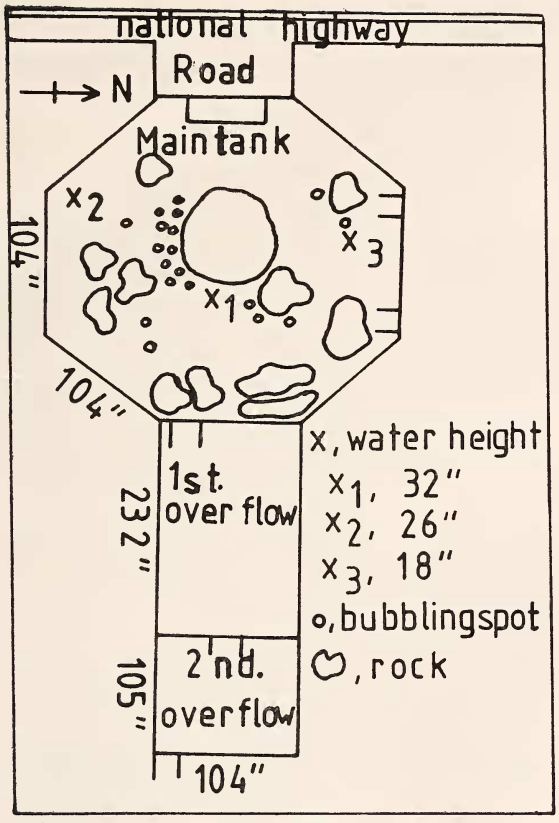

Fig. 1. Diagramatic representation of the study site of the hot water spring at Taptapani.

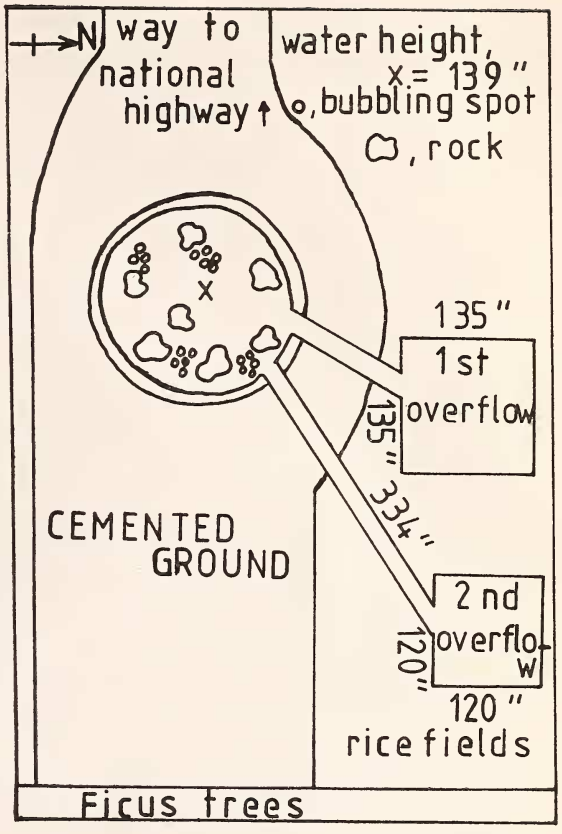

Fig. 2. Diagramatic representation of the study site of the hot water spring at Autri.

over flows of the thermal springs through a plankton net made of standard bolting silk cloth (No. 21 with 77 meshes/sq. cm.). The concentrated plankton was preserved in four percent formalin and quantitatively determined by the sedimentation and drop count method. The various phytoplanktons were identified according to Desikachary (1954) and Fritsch (1939).

Results and discussion

The physico-chemical characteristics of the thermal water of the springs of Taptapani and Autri are presented in Table 1 and Table 2. The investigation was carried out to see whether the temperature and pH of both the springs differ from one another and also to find out whether there was any periodic fluctuation of the temperature and pH of an individual spring. From the results (Table 1) the periodic fluctuation of the temperature of both the springs was insignificant and the minor variation may be due to the change of climatic temperature of the regions during different seasons. The local inhabitants state that the temperature of these ther-

TABLE 1

PHYSICAL CONDITION OF THE WATER OF TAPTAPANI AND AUTRI OF ORISSA[1]

Date of investigation	Taptapani Temperature°C			pH	Autri Temperature°C			pH
	Main tank	1st over flow	2nd over flow		Main tank	1st over flow	2nd over flow	
July 1981	44.5	43.5-44.5	40.0-42.0	9.1	56.5	46.5-48.0	46.0-48.0	9.6
Sept. 1981	44.0	43.0-44.0	40.0-41.0	9.2	55.5	45.0-48.0	45.0-48.0	9.7
Nov. 1981	44.0	42.0-43.5	40.0-41.0	9.2	55.0	45.0-48.0	45.0-47.0	9.7
Jan. 1982	44.0	42.0-44.0	40.0-41.0	9.2	55.0	46.0-48.0	46.0-48.0	9.7
March 1982	44.0	43.0-44.0	40.0-41.0	9.2	55.5	46.0-49.0	46.0-49.0	9.8

[1] The water of both the hot springs were clear and produced the characteristic smell of sulphur.

mal springs has remained constant over the past few decades and the location of the fissures have also remained unchanged. There were also reports that many hot springs were constant in their thermal and hydrologic properties over a few hundred years (Brock & Brock 1967, Stockner 1968, Castenholz 1969). The slightly low pH of the water during July may be due to the inflow of rain water from the surrounding area. It has been analysed that the water of both the hot springs were free of CO_2. There were reports (Brock & Brock 1966) that light and CO_2 were not the limiting factors for phytoplankton production in alkaline hot springs. The water sample of both the thermal springs investigated had traces of nitrate, nitrite and phosphorus (Table 2). However, chloride, carbonate and silicate were present at various proportions which normally is not found in fresh water pools. In addition sulphurated hydrogen was present in the spring water, which emit H_2S gas smell. Total solids and dissolved oxygen of the water of Taptapani was more in comparison to the thermal water of Autri (Table 2). These physico-chemical characteristics of the hot water springs were mainly responsible for the growth of various organisms in the spring water.

TABLE 2

CHEMICAL CHARACTERISTIC OF THE WATER FROM TAPTAPANI AND AUTRI OF ORISSA

Constituents	Water from the main tank of Taptapani (1)	Water from the main tank of Autri (2)
Free CO_2	Nil	Nil
Total solids (ppm)	580	240
Total hardness ($Ca\ CO_3$) (ppm)	9.8	14.0
Chloride (Cl^-) (ppm)	92.0	130.0
Nitrate (NO_3^-) (ppm)	trace	trace
Nitrite (NO_2^-) (ppm)	trace	trace
Phosphate (PO_4^-) (ppm)	trace	trace
Silicate (SiO_3^-) (ppm)	48.0	33.6
Dissolved O_2 (ppm)	4.9	1.4
Sulphurated hydrogen (as H_2S)	Present	Present

(1) = Collected on 10.2.1982.

(2) = Collected on 12.2.1982.

TABLE 3

DISTRIBUTION OF PLANKTON IN THE MAIN TANK AND OVER FLOWS OF TAPTAPANI AND AUTRI OF ORISSA

	Taptapani			Autri		
	Main tank	1st over flow	2nd over flow	Main tank	1st over flow	2nd over flow
Total plankton/ 1000 ml	438,080	322,650	150,470	650	290,200	248,560
Total zooplankton/ 1000 ml	14,150	10,820	4,400	Nil	18,600	22,350
Zooplankton percentage	3.23	3.35	2.92		6.4	8.99
Total phytoplankton/ 1000 ml	423,930	311,830	146,070	650	271,600	226,210
Phytoplankton percentage	96.76	96.64	97.07	100	93.59	91.0

TABLE 4

OCCURRENCE OF VARIOUS ORGANISMS IN THE MAIN TANK AND THE OVER FLOWS OF TAPTAPANI AND AUTRI OF ORISSA

Organism	Taptapani			Autri		
	Main tank	1st over flow	2nd over flow	Main tank	1st over flow	2nd over flow
Synechococcus lividus (Copeland)	++	++	++	–	–	–
Synechococcus elongatus (Näg)	++	++	++	–	–	–
Synechosystis aquatilis (Sanv.)	+	+	+	–	–	–
Aphanothece sp.	+	+	+	–	–	–
Chroococcus minor (Nätz) Näg	++	++	++	–	++	++
Oscillatoria teribriformis (Ag.)	++(+)	++	++	++(+)	++(+)	++(+)
Oscillatoria princeps (Vauch.)	–	–	–	–	+	+
Oscillatoria tenuis (Ag.)	–	–	–	–	+	+
Phormidium purpurascens (Kütz) Gom.	+	+	+	–	+	+
Phormidium sp.	–	–	–	–	+	+
Lyngbya sp.	+	+	+	–	+	+
Spirulina sp.	++	++	++	–	++	++
Anabaena sp.	+	+	+	–	+	+
Mastigocladus laminosus (Cohn)	++(+)	++	++	++(+)	++(+)	++(+)
Cosmarium sp.	+	+	+	–	+	+
Scenedesmus sp.	–	–	–	–	+	+
Cyclotella sp.	++(+)	++	++	++(+)	++(+)	++(+)
Navicula sp.	++(+)	++	++	++(+)	++(+)	++(+)
Euglena sp.	+	+	+	–	+	+
Tobrilus sp.	+	+	+	–	–	–
Cyclops sp.	+	+	+	–	+	+
Lacane sp.	–	–	–	–	+	+
Nauplius larva	+	+	+	–	–	–

+ = Present; – = absent; ++ = Occur abundantly; (+) = Occur throughout the year.

The thermal water of Taptapani encouraged the growth of a number of organisms mostly phytoplanktons which imparts deep green coloration to the spring. Quantitatively, highest plankton population was observed in the main tank of Taptapani. In its overflows the plankton population was a little less and in the 2nd over flow the number of planktons was reduced. Since both the overflows are normally used for bathing, the mats were partially cleared by the tourists. The high temperature of the clear water of Autri do not encourage the growth of a large number of plankton. The over flows, where the temperature of the water was less there was luxurious growth of various organisms. Zooplanktons were totally absent in the main tank of Autri. This may be due to the higher temperature of the spring. However, abundance of phytoplankton and zooplankton were noticed in both of its over flows. Due to higher water depth of the over flows of Autri, the tourists normally do not enter the tanks for bathing, thus do not disturb the growth of the plankton mats. The plankton mats collected from various spots of the main tank and over flows of both the thermal springs composed of mostly members of cyanophyceae, diatoms and a few zooplankton (Table 3). Similar gelatinous and calcareous mats of various colours consisting of blue-green algal cells have also been reported in other hot springs of Europe and America (Castenholz 1969, Stockner 1967). From these results it seems that the temperature may be the major factor in determining the qualitative and quantitative distribution of planktonic organisms. The differences in the floristic pattern and the productivity of the hot springs may be due to the difference in concentration of the mineral elements of the spring water.

Of the various thermophilic organisms, only *Chroococcus minor* (Nätz) Näg., *Oscillatoria teribriformis* (Ag.), *Spirulina* sp., *Mastigocladus laminosus* (Cohn), *Cyclotella* sp. and *Navicula* sp. occur in both the hot water springs and in addition *Synechococcus lividus* (Copeland) and *Synechococcus elongatus* (Näg.) occur abundantly in Taptapani. In addition a number of blue-green algal forms, green algae, *Euglena* and various zooplanktons were also observed in the thermal water (Table 4). Certain thermophilic organisms, viz. *Oscillatoria teribriformis* (Ag.), *Mastigocladus laminosus* (Cohn), *Cyclotella* sp. and *Navicula* sp. occur abundently in the thermal water even at 55°C in the hot water spring of Autri throughout the year of investigation. There are records that a large number of *Spirulina* sp., *Chroococcus* sp., *Aphanothece* sp. *Anabaena* sp., *Oscillatoria* sp., *Navicula* sp. and *Cyclotella* sp. have been collected from thermal springs with 26-50°C temperature range (Gonzalves 1947, Prasad & Srivastava 1965, Vasistha 1968). There were also reports that *Oscillatoria* sp. has the ability to grow at high temperature in various thermal springs of India (Gonzalves 1947, Prasad & Srivastava 1965). The occurrence of a common thermophilic blue-green alga *Mastigocladus laminosus* (Cohn) (Castenholz 1970) at temperatures upto 55°C in the thermal water of Taptapani and Autri of Orissa is a new record from Indian thermal springs.

S. P. ADHIKARY[1]
JAYANTI SAHU

DEPARTMENT OF BOTANY,
DHARANIDHAR COLLEGE,
KEONJHAR 758 001, ORISSA.
July 16, 1985.

[1] *Present address*: Dept. of Botany, Utkal University, Bhubaneswar 751 004, Orissa.

References

American Public Health Association (1965): Standard method for the examination of water and waste water. 12th. Ed. A.P.H.A., Inc. N.Y.

Brock, T. D. & Brock, M. L. (1966): Temperature optima for algal development in Yellowstone and Iceland hot springs. *Nature, 29*: 733-734.

——————————— (1967): The hot springs of Furnas Valley, Azores. *Int. Revue. Ges. Hydrobiol., 52*: 545-558

——————————— (1968): Measurements of steady state growth rates of a thermophilic alga directly in nature. *J. Bact., 95*: 811-815.

——————————— (1969): Effect of light intensity on photosynthesis by thermal algae adapted to natural and reduced sun light. *Limnol. Oceanogr., 14*: 334-341.

Castenholz, R. W. (1967): Aggregation in thermophilic *Oscillatoria. Nature, 215*: 1285-1286.

——————————— (1968): The behaviour of *Oscillatoria teribriformis* in the hot springs. *J. Phycol., 4*: 132-139.

——————————— (1969): Thermophilic blue-green algae and thermal environment. *Bact. Rev., 33*: 476-504.

——————————— (1970): Laboratory culture of thermophilic cyanophytes. *Schweiz Z. Hydrobiol., 24*: 1-24.

Desikachary, T. V. (1954): Cyanophyta. I.C.A.R. monograph on algae, New Delhi.

Drouet, F. (1938): Myxophyceae of the Yale North Indian Expedition, collected by G. E. Hutchinson. *Trans. Amm. Microbiol. soc., 57*: 127-131.

Fritsch, F. E. (1939): Structure and reproduction of Algae, Vol. I & II, Cambridge University Press, U.K.

Gonzalves, E. (1947): The algal flora of the hot springs of Vajreswari near Bombay. *J. Univ. Bombay., 16*: 22-27.

Kahan, D. (1969): The fauna of hot springs. *Verh. Internat. verein. Limnol., 17*: 811-816.

Kirtikar, K. R. (1886): A new sp. of algae *Conferva thermalis birdwoodii. J. Bombay nat. Hist. Soc., 1*: 135-138.

Oldham, T. & Oldham, R. D. (1882): The thermal springs of India. *Mem. Geol. Survey India., 19*: 99-161.

Prasad, B. N. & Srivastava, P. N. (1965): Thermal algae from Himalayan hot springs. *Proc. Nat. Inst. Sci. India, 31*B: 45-53.

Stockner, J. G. (1967): Observations of thermophilic algal communities in mount Rainer and Yellow stone National parks. *Limnol. Oceanogr., 12*: 13-17.

——————————— (1968): Algal growth and primary productivity of a thermal spring. *J. Fish Res. Bd., Canada, 25*: 2037-2058.

Thomas, J. & Gonzalves, E. A. (1965): Thermal algae from Western India. *Hydrobiol., 26*: 21-65.

Vasistha, P. C. (1968): Thermal cyanophyceae of India. Ph.D. thesis, University of Chandigarh, India.

Fig. 1. Diagramatic representation of the study site of the hot water spring at Taptapani.

Fig. 2. Diagramatic representation of the study site of the hot water spring at Autri.